AIRS/AMSU/HSB Version 5 Changes from Version 4

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June, 2007

Version 1.0

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Introduction

In the absence of a failure of AMSU forcing a change over to our AIRS-only mode of retrieval (i.e., infrared-only retrievals), the basic retrieval methodology has changed only slightly between V4 and V5. However, we have updated the RTA, corrected several problems in the V4 data products, modified channel sets, and added new quality indicators and products. The changes, from Level 1 through Level 3 processing, mean that all data products will be slightly different in V5 when compared to previous versions. The new quality indicators and error estimates will impact the way the user filters data products. The new data products expand research options.

The version numbers that appear in the AIRS Product Files are slightly different, depending upon the product due to a staged delivery of processing code to the GES DISC. They are:

- **All Level 1B Products**: v5.0.0.0 (with one exception)
- **Level 1B Calibration Subset Product**: v5.0.16.0
- **All Level 2 Products**: v5.0.14.0
- **All Level 3 Products**: v5.0.14.0

Calibration/Validation Status

The status of V5 calibration/validation is provided in the document:

V5_CalVal_Status_Summary.pdf

The significant change is the expansion of the geographical extent to include polar regions.

Changes from V4 to V5

New Processing Platform

The processing software now executes on a new platform (LINUX instead of SGI CPUs running under the IRIX operating system), such that there may be small differences (less than 0.0001) in floating point values for computed values, such as radiances. This may also slightly affect the geolocation of calculation of granule boundaries.

Level 1B Processing Stage

- A small change was made to the Planck constant used in radiance calculations, to bring it into conformity with other PGE process and products. This also will slightly affect the calculated Level 1B results.
- The calculation of the AMSU-A Level 1B antenna brightness temperature has two changes: the calculation now includes a side-lobe correction factor plus tuning and the temperature error calculation is now fully implemented for the first time.
- There is a substantial change in the way NeDT is calculated for AMSU-A and HSB, and the names of the fields have been modified.
- The AIRS Level 1B Moon-in-View algorithm was substantially revised. Specifically, under moonlit space view conditions, in many cases substantially more scans will be flagged with Moon-in-View and subsequently omitted from the dark space view offset calculations and NeN. The previously undetected Moon intrusions were not large enough to make much difference in the calculated radiances, but they did tend to increase the measured NeN and therefore result in many channels being flagged as "noise out of bounds" in the **CalChanSummary**.
- The NeN calculations have been modified to better handle partial granules. Previously, calculated NeN spuriously increased and many channels were flagged as "noise out of bounds" in a partial granule.
- The nominal frequencies for channels 1-130 in module M12 have been shifted (see discussion of changes in RTA).
- AMSU-A2 temperatures changed due to correction (added in V5) for capacitor failure in AMSU-A2 board involved in temperature sensing and conditioning. This is a change in the DN-EU conversion process which should be carried forward in all subsequent PGE versions but which is missing from V4 and earlier.
- The Level 1B AIRS science data products now contain the new parameters known as spectral_clear_indicator, SO_2 flag, dust flag, and dust score.
- Miscellaneous parameters have been dropped from some data products entirely or shifted/added to other products in response to requests from the user community. The AMSU NEDT ratio parameter, for example, was dropped as there is currently no consensus as to an appropriate baseline for this normalized parameter. The exact tally of these parameter changes is shown in the Data Baseline Consistency test results.

Level 2 Microwave-Only Retrieval Stage

AMSU-A Tuning

Adjustments for AMSU-A measurements were developed to obtain consistency with AIRS measurements in clear-air ocean cases taken from the period August 2003 to December 2005. The clear-air cases were identified as follows: In the first pass, the V4 retrieval was run on all data. If the nine AIRS spots within an AMSU-A FOV passed the retrieval's clear tests for uniformity and agreement with AMSU-A, and if the cloud-cleared AIRS radiances also passed the radiance clear and aerosol tests, then an AIRS-only retrieval was re-run on those cases. The second pass retrieval did not perform cloud-clearing; the radiances of the nine AIRS spots were averaged and processed as clear. However, any retrievals with high residuals were rejected. Then brightness temperatures were computed from the AIRS-retrieved temperature and moisture profiles at the AMSU-A frequencies, using the microwave rapid transmittance algorithm. In approximately 1% of the remaining cases, the difference between observed antenna temperature and computed brightness temperature for AMSU channel 6 deviated by more than 1K (~3 standard deviations) from its mean value at each AMSU scan position. These channel-6 outliers were predominantly positive, indicating some remaining cloud contamination in those retrieved profiles, which were therefore rejected. Any cases where sea ice was detected by the AMSU surface classification were also excluded. The remaining ~161,000 profiles provided several thousand cases at each scan position. The differences between observed antenna temperature and computed brightness temperature represent the combined contributions of antenna sidelobes and any forward-model errors. The mean value of the difference at each scan position and channel is used as a bias correction for AMSU-A.

The corrections used in V4 Level 2 were calculated from ECMWF analysis fields. The V5 calculations based on AIRS are about 1K warmer than for ECMWF in the stratosphere, thus the new corrections are smaller for AMSU channels 11-14. For the sounding channels at lower altitudes in the atmosphere (AMSU 4-10), changes from V4 are less than in the stratosphere, but they also help to produce greater compatibility of the two sounding instruments.

Calculation of brightness temperatures for the window channels of AMSU-A requires a model for the surface emissivity and its scattering characteristics, both of which depend on near-surface wind speed, over the ocean. Using the large dataset of clear-air AIRS retrievals of atmospheric temperature and moisture together with wind speed from NOAA's AVN model, the dependence of emissivity on wind was determined as the slope in a linear regression. The wind-induced emissivity increment was added to a Fresnel emissivity calculated from the

dielectric constant model of Ellison *et al* (2003). The downwelling sky brightness was calculated using a model based on the results of Rosenkranz and Barnet (2006). The surface roughness model for channel 3 was also used for calculation of channels 4 and 5 brightness temperatures, which are influenced to a lesser extent by the surface. Although the observed-calculated biases are always negative for the window channels, which is consistent with the influence of cold space in the far sidelobes of the antennas, their dependence on scan position is not as expected; the near-nadir positions show some of the largest biases. Thus, there may be contributions to the biases from errors in the surface model, from inconsistency between the microwave and infrared models for absorption by water vapor, or from undetected clouds. Although these results are not yet perfectly understood, tests with the new values for the bias corrections on AMSU channels 1-14 showed a slight improvement in retrieval accuracy compared to the previous version. On that basis, the AIRS team decided to use them in V5 of the operational software. In V5 these corrections have been made to AMSU-A brightness temperatures in Level 1B also, whereas in V4 Level 1B the brightness temperature and antenna temperature fields were equal.

References:

Ellison, W. J., S. J. English , K. Lamkaouchi, A. Balana, E. Obligis, G. Deblonde, T. J. Hewison, P. Bauer, G. Kelly and L. Eymard (2003), A comparison of ocean emissivity models using the Advanced Microwave Sounding Unit, the Special Sensor Microwave Imager, the TRMM Microwave Imager, and airborne radiometer observations, JGR, 108(D21), 4663, doi:10.1029/2002JD003213.

Rosenkranz, P. W., and C. D. Barnet (2006), Microwave radiative transfer model validation, JGR, 111, D09S07, doi:10.1029/2005JD006008 .

Microwave Surface Classification

To eliminate some spurious sea-ice detections that result from rain contamination, a test for warm surface temperature was added to the surface classification routine in V5.

Yield over Sea Ice

In the Level 2 retrieval algorithm, the apriori variance of sea ice brightness temperature was increased. This change improves the yield for this type of surface by allowing the retrieval a larger fitting range.

Cloud Liquid Water over Land

The V4 microwave-only retrieval algorithm, when run without HSB data, was vulnerable to a trap involving excessive water vapor and unrealistic liquid water over deserts, which caused the retrieval to be rejected and prevented the Level-2 PGE from proceeding to later stages. In V5, this is avoided by biasing the apriori value of the condensation point to 116% relative humidity over land surfaces, when HSB data is absent. Although the water vapor is still not correct at that point, the PGE then proceeds to stages where AIRS data is included, which corrects the vapor profile. Without HSB, the cloud liquid water is considered invalid over land.

HSB Transmittance

The HSB transmittance coefficients were adjusted to provide improved agreement of the rapid algorithm with a line-by-line calculation, when data from the period of HSB operation is re-processed.

Addition of AIRS-Only Level 2 Retrieval Capability

Currently AIRS and AMSU form an instrument suite and the Level 1 data from both instruments are normally combined in the Level 2 processing to produce a single Level 2 product. AIRS is the critical instrument, and a contingency plan is ready in the event of failure of AMSU. V5 includes an AIRS-only capability in the Level 2 software which produces results as good as the combined AIRS/AMSU product except under very cloudy conditions. If AMSU should fail, the V5 processing will shift to AIRS-only, as will the reprocessing of earlier data.

Modification of Level 2 Retrieval Flow

The sequence of retrieval steps is slightly different between V5 and V4. The major changes are:

- Addition of an AIRS-Only retrieval capability (i.e., no microwave information used) to be used in the event of failure of AMSU.
- Addition of a cloudy regression stage to the retrieval algorithm after the initial MW-Only retrieval stage.
- Compaction of the physical retrieval stage, removing iteration between cloud clearing and physical retrieval.

See **V5_Retrieval_Flow.pdf** for a step-by-step comparison of V4, V5 and V5 AIRS-Only retrieval flow.

RTA Update

The AIRS fast forward model used by V5 (AIRS RTA V5) is the same basic model as used in V4, but with some algorithm changes and additions to improve the accuracy and increase flexibility. The changes and additions are:

- Improved tuning of the transmittances
- Improved frequencies for channels 1-130
- Improved estimate of reflected downwelling radiance
- New daytime radiance contribution for non-LTE emission
- Implementation of a CO_2 profile
- Addition of variable trace gases: N_2O, SO_2 and HNO_3

These changes for V5 are discussed in more detail below.

Transmittance Tuning

The transmittance tuning (applied as optical depth multipliers) used in V4 was based on a limited amount of validation data available at the time the fast model was finalized in January 2004. Over the next two years a much larger amount of validation data become available, and this has been used to improve the transmittance tuning in V5. A more detailed discussion of the validation data and the effects of tuning can be found in [Strow et al 2006, reference given below].

For the most part the changes to tuning are relatively minor, affecting computed Brightness Temperature (BT) spectra at the few tenths of a Kelvin level or less. The main change is to "fixed" gases in the 15 and 4.3 μm regions. Unlike V4, the V5 tuning was extended to stratospheric channels (based upon AIRS retrievals, as very little in situ validation data is available). The tuning of the 4.3 μm channels took into consideration non-LTE effects. Some relatively minor changes were made to tuning in shortwave channels affected by N_2O.

The changes to water tuning are minor, the main changes being near 880 and 1320 cm^{-1} where the old tuning appeared to have been influenced by HNO_3. The CH_4 tuning near 1305 cm^{-1} was adjusted by 2% on the recommendation of the retrieval team to reduce biases in retrieved CH_4. Finally, a significant change has been made to ozone in the 10 μm region. This tuning attempts to account for changes to ozone line parameters in the recent HITRAN 2004 databases versus the HITRAN 2000 upon with the V5 fast model is based.

Reference:

Strow, L.L., S. E. Hannon, S. De Souza-Machado, H. E. Motteler, and D. C. Tobin (2006), Validation of the Atmospheric Infrared Sounder radiative transfer algorithm, JGR, 111, D09S06 (2006), doi:10.1029/2005JD006146

Channel Frequencies

An error in the frequencies of channels 1 to 130 (detector module 12) has been corrected for V5. The V5 channels have been shifted approximately +1.5% of a channel width compared to V4. New fast model coefficients were generated for the shifted channels based upon revised model SRFs. No other channels are affected. The effects on BT spectra are on the order of a few tenths of a Kelvin or less. This error was present in all data releases previous to V5.

Reflected Downwelling Radiance

The algorithm used to estimate the radiance contribution from reflected downwelling atmospheric thermal emission has been totally redone for V5. The new algorithm required some restructuring of the radiative transfer code for computational efficiency, but it provides a more accurate estimate at little extra computational cost. Over ocean and other low reflectivity surfaces, the reflected downwelling term is typically on the order of a few tenths of a Kelvin in the window channels and negligible in non-window channels. However, over more reflective surfaces the radiance contribution can be much larger, and here the improved algorithm for V5 may help.

For V5 the reflected downwelling thermal radiance contribution is first computed as a downward radiance at the surface in manner similar to the calculation of the main upward thermal radiance. This radiance is multiplied by a fudge factor "F" to adjust for the use of the same layer transmittances used by the upward radiance calculations, as these are not quite mathematically correct when used for downwelling radiances. The "F" factor is calculated using predictors based on the surface-to-space transmittance, the secant of the viewing angle, and the downward radiance, with coefficients determined by regression. The total reflected downwelling thermal radiance reaching AIRS is the the downward radiance at the surface times the surface reflectivity (times π) and the surface-to-space transmittance.

Daytime non-Local Thermodynamic Emission

New coefficients and code were added to model the effects of daytime non-LTE (deviation from local thermodynamic equilibrium) in the atmosphere above the 1 mb level. Preferential absorption of sunlight by CO_2 and other molecules resulted in daytime biases of up to 12 K in the 4.3 μm band, making it difficult to use for temperature sounding. With this enhancement, the daytime biases are reduced to levels similar to the nighttime biases, where non-LTE is not present. As a result we have incorporated 4.3 μm radiances into our temperature sounding, and the tuning coefficients with respect to radiosondes are smaller than they would be otherwise.

The non-LTE radiance contribution is computed as an independent term added to the standard (LTE) radiance. This non-LTE radiance is calculated using predictors based on the solar and satellite zenith angles as well the mean temperature in the top five AIRS layers, with coefficients determined by regression.

Reference:

DeSouza-Machado S. G., L. L. Strow, S. E. Hannon, H. E. Motteler, M. Lopez-Puertas, B. Funke, D. P. Edwards (2007), Fast forward radiative transfer modeling of 4.3 µ m nonlocal thermodynamic equilibrium effects for infrared temperature sounders, Geophys. Res. Lett., 34, L01802, doi:10.1029/2006GL026684.

Implementation of CO_2 Profile

The algorithm responsible for handling the variability of trace gas CO_2 was modified to allow for more flexibility. In V4 the CO_2 variability was limited to an overall profile scale factor, while in V5 the CO_2 may be independently varied in each AIRS layer. This change will allow AIRS computations to make use of climatologically based CO_2 profile shapes rather than being restricted to the default US Standard profile shape. At present, V5 climatology assumes a time-dependent constant profile (see discussion below), and CO_2 is not retrieved in the V5 PGE.

Addition of Variable Trace Gases N_2O, SO_2 and HNO_3

For V5 new code and coefficients have been added to allow for variability in trace gases N_2O, SO_2, and HNO_3. These gases were previously "fixed" in the V4 and early AIRS fast models. The implementation of the variability for each of these gases is similar to how we handled the variability of CO_2. None of these gases are currently retrieved in the V5 PGE.

N_2O (nitrous oxide) is fairly well mixed in the atmosphere and is only expected to vary by a a few percent around the mean. N_2O absorption has a significant affect on AIRS radiances in three spectral regions: moderately at 1250-1320, strongly at 2180-2250, and weakly at 2450-2600 cm^{-1}. The effects of variable N_2O on AIRS BT spectra are estimated to be at the couple tenths of a Kelvin level.

SO_2 (sulfur dioxide) is typically present in the atmosphere at too low a concentration to be detectable to AIRS. However, volcanic eruptions often emit large amounts of SO_2 and push it high into the troposphere, and these volcanic plumes are often detectable using AIRS. SO_2 absorption affects AIRS radiances in three spectral regions: weakly at 1100-1137, strongly at 1330-1390, and very weakly at 2470-2520 cm^{-1}. The effects of variable SO_2 on AIRS BT spectra can be anywhere from zero to tens of Kelvins, depending on how much SO_2 is present.

HNO_3 (nitric acid) is present in the atmosphere at a level at which the climatic and season variations are detectable by AIRS. Most of the HNO_3 is located in the stratosphere, and it tends be at low amounts in the tropics and larger amounts at high latitudes. HNO_3 affects AIRS radiances with similar strength in two spectra regions: the 850-920 cm^{-1} window region, and the 1280-1350 cm^{-1} lower/mid troposphere water region. The global variation in HNO_3 results in change to AIRS BT spectra on the order of a few tenths of a Kelvin.

Time Variable CO_2 Climatology

In V4 and earlier, the CO_2 was assumed to be constant over time and fixed throughout the atmosphere at 370 ppmv. The RTA remains linear for deviations from this value of ±10 ppmv. V5 incorporates a global average linear time-variable CO_2 to assure linearity for the indefinite future:

$$CO2\_ppmv(t) = A + B \bullet (t-t0)$$

Where A = 371.92429, B = 1.840618, t0 = 1/1/2002 @ 0UT, t = current date/time and (t-t0) is expressed in years and fraction of year. Although a CO_2 profile is now part of V5, all elements are set to the climatology CO_2 for the date and time of the AIRS retrieval. The associated quality factor, Qual_CO2, is always set to the value 2 because CO_2 is not retrieved in V5.

Day/Night Boundary and the Retrieval of Reflectivity

In V4, retrievals with solar zenith angle greater than 85 deg were considered to be night cases and the retrieval of bidirectional solar reflectance was not attempted. During testing of V5 before delivery, it was discovered that this artificial day/night boundary produced a discontinuity. Thus in V5 the day/night boundary has been changed to the solar zenith angle of 89.9 deg. This change only affects polar cases due to the 1:30 AM/PM sun synchronous orbit of Aqua.

This does not carry over to the VIS/NIR product. The VIS/NIR product is not created when a granule's **DayNightFlag** is "Night". This occurs when the solar zenith angle of the subsatellite point (not an FOV) at both the beginning and the end of the granule is greater than 90 degrees. Some of the discarded granules do have corner FOVs with solzen < 90 degrees, but that discarded data volume is miniscule.

Surface Emissivity Retrieval

The surface emissivity retrieval over ocean FOVs is changed slightly due to a change in the retrieval channel set. Differences between V4 and V5 are not measurably significant.

The land surface emissivity has been significantly improved in V5. The regression training set and surface retrieval radiance channel set have been modified. The result is improved retrieved emissivity over heavily vegetated surfaces and fewer emissivities reported greater than 1.0. These improvements have also resulted in fewer fictitious low clouds over deserts in V5.

Modifications to Regression Stage

In V4, we applied the "initial regression" to the cloud cleared radiances. The V5 algorithm applies an additional regression, "cloudy regression", to the cloudy AIRS radiances. The "cloudy regression" is applied to the warmest AIRS spot among the 9 in the AMSU FOV, i.e. the spot with the greatest radiance in the 1231.3 cm^{-1} channel. Besides using the first 85 principal component scores computed from the AIRS radiances, it also uses some of AMSU brightness temperatures as input. This improves upon the MW-Only retrieval in the event that the scene is relatively clear.

In V5, the regression temperature in the upper stratosphere to mesosphere is modified to match UARS climatology.   The purpose was to improve the non-LTE correction. The AIRS instrument is not very sensitive to the portion of the atmosphere.

The channel set for regression has not changed between the versions. However there are a few channels that have degraded since launch. As a consequence, a greater number of channels used in the regression is estimated from other channels.   The impact of this channel filling is not presently known.

In V4, there was only one surface regression over none-ocean surfaces (either frozen ocean or land).   In V5, there are separate surface regressions: one for land surface and another for frozen surface.   The earlier emissivity regression over ocean has been replaced with a model some time ago and is not used in either V4 or V5.

The eigenvector coefficients and the initial regression coefficients for T, H_2O, O_3 are identical in V4 and V5. The only coefficient changes are for the surface regression and the cloudy radiance regression. The training for the cloudy regression is based on the same eigenvector coefficients in V5 as in V4. However, the regression is applied to the cloudy radiances in V5 rather than to the cloud-cleared radiances as was done in V4.

In V4, we use AMSU produced total precipitable water to adjust the water vapor regression. In V5, the AMSU adjustment for total precipitable water is turned off because AMSU is no longer as accurate in total precipitable water due to the loss of HSB.

Empirical Error Estimates

V5 employs empirical error estimates for the quality control of both Level 2 products and Level 3 products. See the document:

V5_L2_Quality_Control_and_Error_Estimation.pdf

Modified Channel Sets Used in the Retrieval Stages

See **V5_Retrieval_Channel_Sets.pdf** for a list of the channel sets used by the retrieval algorithm, identified by function. It also contains a figure showing their location in the AIRS spectrum.

- The cloud clearing and cloud parameter retrieval channel set has been reduced over land, removing channels that see the surface.
- The tropospheric temperature sounding retrieval stage has been modified to use only the 4 μm channels.
- The channel set employed by the O_3 retrieval stage has been modified to increase sensitivity.

VIS/NIR Derived Cloud Fields Removed

In the V5 release, the cloud fields derived via the visible/near-infrared radiances have been removed from the Level 2 product. The field names in V4 were **CldFracVis, CldFracVisErr, ClrFracVis, ClrFracVisErr, vis_clear, vis_cloud** and **vis_low_cloud**.

Level 2 Standard Product QA and Error Estimates

The most important change between V4 and V5 visible to the user of AIRS products is the enhanced product-specific quality indicators and improved error estimates. Please read the documentation for an extended discussion of these quality indicators and the estimated errors.

V5_L2_Quality_Control_and_Error_Estimation.pdf

The quantities on which the new quality indicators are based are included in the Level 2 Support Product. We do not encourage second-guessing of the threshold values that were used to set the quality indicators in the Level 2 Standard Product. However we do offer caveats and suggestions by which users may further refine their filtering of retrieved products in

V5_L2_Standard_Products_Quickstart.pdf.

We urge researchers to carefully read both these documents.

With the relaxation of quality control for land surfaces and tightening of quality control over the ocean surface, the surface temperature yield over land areas has improved while the surface temperature yield over the ocean has dropped slightly in V5. We have found general improvement over the desert regions in V5. Dropouts (total failure of the retrieval algorithm) still occur, but they are much improved in V5. We fill the fields of dropouts with -9999 rather than with some substitution value (e.g., climatology). The yield for atmospheric parameters is generally much larger in V5 than in V4.

We noticed in our testing of V5 before delivery that the yield of some AIRS products has degraded slightly across the time span of AIRS data coverage. For reasons not yet well understood, the yields have dropped as a function of time since orbit insertion.

Error Corrections to Existing Products

Level 2 Standard and Level 3 Outgoing Longwave Radiance (OLR) Product

A significant coding error was present in the V4 calculation of outgoing longwave radiation, **olr**, which resulted in overestimating it when high clouds were present in the scene, especially near the ITCZ. The clear sky outgoing longwave radiation, **clrolr**, was not affected by this error. The coding error has been corrected in V5.

As in V4, the outgoing longwave radiation (**olr**) is not directly measured, but is calculated from the retrieved state using a separate rapid algorithm documented in Mehta and Susskind (1999) and NASA Technical Report GSFC/CR-1999-208643. The surface emissivity in spectral regions not measured by AIRS is assumed to be the same as at the nearest spectral point for which an emissivity is obtained. The effective cloud fraction (cloud fraction multiplied by cloud emissivity) is assumed constant throughout the spectrum and is retrieved based on the 11 micron region.

The clear-sky outgoing longwave radiation (**clrolr**) is also not directly measured, but is calculated from the retrieved state using a separate rapid algorithm documented in Mehta and Susskind (1999) and NASA Technical Report GSFC/CR-1999-208643. The surface emissivity in spectral regions not

measured by AIRS is assumed to be the same as at the nearest spectral point for which an emissivity is obtained.

References:

NASA Technical Report GSFC/CR-1999-208643

Mehta and Susskind (1999), JGR volume 104, number D10, pp. 12193-12212.

Level 2 Standard Saturation and Level 3 Relative Humidity Product

The erroneous calculation of the V4 Level 2 moisture saturation profile, which propagated through to the Level 3 relative humidity product, has been corrected in V5.

The V4 saturation mixing ratio was calculated at the temperature of the standard pressure levels using Buck (1981). The calculation took into account the shift from liquid to ice at 273.15 K, but the saturation profile was not integrated over each layer. Instead, it was a level quantity at the standard pressure levels. It could not be directly compared to the observed moisture profile, which is a layer quantity. Doing so would result in absurd estimates of relative humidity, the most benign effect being a dry bias.

In V5, the saturation mixing ratio profile is properly integrated over each layer. In fact, there are two saturation mixing ratios provided, **H2OMMRSat_liquid** and **H2OMMRSat** . They both provide profiles of the integrated mass of water vapor in saturated equilibrium between levels divided by the integrated mass of dry air. **H2OMMRSat_liquid** assumes equilibrium with liquid water. **H2OMMRSat** is in equilibrium with liquid so long as the temperature profile exceeds 273.15 K. If the temperature profile drops below that threshold, the saturation calculation shifts to that over ice. Thus within a layer in which the temperature crosses 273.15 K, the calculation will shift between saturation over liquid to that over ice to derive its integrated mass of water vapor. Near the surface the two saturation profiles are identical, but they will diverge in the case that the temperature profile crosses the threshold. The constituent relationship employed is that of Murphy and Koop (2005).

References:

Murphy, D. M. and T. Koop (2005), Review of the vapour pressures of ice and supercooled water for atmospheric applications, Quart. J. Royal Met. Soc, 608 Part B, 1539-1565.

Buck, A. L. (1981), New equations for computing vapor pressure and enhancement factor, J. Appl. Meteorol., 20, 1527-1532.

Enhancements to Existing Products

Please refer to **V5_L2_Standard_Product_QuickStart.pdf** for a detailed discussion of each AIRS Level 2 Standard Product.

Level 2 Standard Temperature Products

The V5 temperature product has improved quality indicators, **PBest** and **PGood**, and improved estimated errors. The quality indicators allow finer vertical discrimination of the point at which the retrieval of the temperature profile begins to encounter difficulties, and the result is a smoother gradient in yield from the top of the atmosphere to the surface. The error estimate in V5 has improved over that in V4. Thus we have been able to relax the quality control thresholds somewhat and increased yield as a result.

Level 2 Standard H_2O Products

The H_2O product now has its own 15-level pressure level array, **pressH2O**. Previously it had been reported on the 28-level standard pressure level array, **pressStd**, shared by the temperature product. The **pressH2O** array is the same as the first 15 elements of the **pressStd** array, i.e. it terminates at 70mb pressure. AIRS has no sensitivity to moisture above that level.

The saturation equilibrium profile calculation has been corrected in V5 and now appears in the H_2O product as true layer integrated profiles in two forms, **H2OMMRSat_liquid** and **H2OMMRSat**. See the previous discussion, "Level 2 Standard Saturation and Level 3 Relative Humidity Product."

A new field has been added to the H_2O product, **H2O_verticality**.

H2O_verticality is an 11 point vector computed by summing the columns of the 11x11 H_2O averaging kernel, **H2O_avg_kern**, stored in the AIRS Level 2

Support Product. The peak of **H2O_verticality** indicates the vertical location of the maximum sensitivity of the H_2O product and the magnitudes of **H2O_verticality** are a rough measure of the fraction of the retrieval determined from the data as opposed to the first guess. Values near unity should be considered highly determined from the measurement, while smaller values indicate the retrieval contains a large fraction of the first guess.

Level 2 Standard O_3 Products

Ozone retrieval methodology for V5 has significantly changed from V4 and as described in Susskind et al. [2003], namely in the derivation of the first-guess, channel selection, and "noise propagation threshold" used in the physical (final) retrieval.

In previous versions, the first guess for the ozone profile was regression-based using European Centre for Medium-Range Weather Forecast (ECMWF) ozone profiles as the training set (see Goldberg et al. [2003]). Instead of using regression, AIRS V5 uses an observationally-based climatology developed for Version 8 TOMS and SBUV [McPeters et al., 2003], which is month-by-month on 10° latitude bins. Using a climatology reduces biases in the mid- to lower-troposphere where AIRS has little sensitivity. Stratospheric biases are about the same. Upper tropospheric biases have been reduced in tropical regions, but somewhat are worse in mid-latitude regions.

To make a look-up table suited to the AIRS retrieval software, ozone mixing ratios were interpolated by latitude and altitude and converted to slab columns on the AIRS 100-level support grid using the "Partial Column" approximation formula in Ziemke et al. [2001]. Where climatological data did not extend the highest or lowest pressure levels of the AIRS support grid, mixing ratio "endpoints" were assumed to extend to such regions.

The channel selection has been extended from 26 (in V4) to 41, and includes the peak of the P-branch in the ozone 10 μm band. Finally, the "noise propagation threshold," DB_{max}, discussed in Susskind et al. [2003], has been effectively doubled, resulting in less damping of the final profile.

Two new fields have been added to the O_3 product, **O3_dof** and **O3_verticality**.

O3_dof provides a measure of the amount of information in the O_3 retrieval. . It is computed by summing the diagonal elements of the 9x9 O_3 averaging kernel, **O3_avg_kern**, stored in the AIRS Support Product files.

O3_verticality is a 9 point vector computed by summing the columns of the 9x9 O_3 averaging kernel, **O3_avg_kern**, stored in the AIRS Level 2 Support Product. The peak of **O3_verticality** indicates the vertical location of the maximum sensitivity of the O_3 product and the magnitudes of **O3_verticality** are a rough measure of the fraction of the retrieval determined from the data as opposed to the first guess. Values near unity should be considered highly determined from the measurement, while smaller values indicate the retrieval contains a large fraction of the first guess.

References:

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Susskind, J., C. D. Barnet, and J. M. Blaisdell (2003), Retrieval of atmospheric and surface parameters from AIRS/AMSU/HSB data in the presence of clouds, IEEE Trans. Geosci. Remote Sens., 41 (2), 390 – 409.

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Level 2 Standard Cloud Products

V5 cloud product is not much changed from that in V4. The cloud parameters solved for are the tops of two flat black clouds at different levels, with different fractions (but not cloud top pressures) among the nine AIRS spots which are contained within the AMSU footprint (and retrieval FOV). In many cases this small number of output parameters may not be very realistic, but the retrieval algorithm finds a best radiative fit to this output format. The cloud clearing algorithm is not constrained to this type of cloud; cloud clearing by its nature works with cloud formations, which can have any fixed vertical structure while varying in cloud amount. Up to four cloud formations are allowed. When an IR retrieval is not possible due to heavy cloud cover, the cloud product is calculated at AMSU resolution. As a result, the fractions reported for all nine spots are set to the same value.

The higher quality temperature and moisture profile retrievals do not correspond to higher quality retrievals of cloud fields. In fact they may have just the opposite quality tendencies. This is not unexpected as a stronger cloud radiative

signature is associated with a more accurate cloud temperature, pressure, and amount. Thus, scenes in which it is more difficult to retrieve temperature and moisture profiles contain more accurate cloud retrievals with smaller associated uncertainties.

Level 2 Standard Surface Emissivity Product

The initial surface emissivity over ocean follows the shape of Wu and Smith (1997) as recomputed at higher spectral resolution by van Delst and Wu (http://airs2.ssec.wisc.edu/~paulv/#IRsse). Their adjustable parameter is set for a wind speed of 5 meters/sec.

Over land and ice, the initial emissivity is set to a flat first guess before carrying out the first cloud clearing.   The subsequent regression retrieval determines a spectral shape that is then used as an updated state for the final retrieval. This regression with shortwave variability has been greatly improved in V5. The final retrieval then adjusts the spectral shape, over land or ocean, with four degrees of freedom. Although algorithm improvements include better treatment of land surface heterogeneity and training over land, the AIRS surface emissivity product over land and ice is still being refined.

There has been considerable confusion over the years about the use of "hinge points" to define the emissivity and reflectvity spectrum. Different retrievals may use different sets of hinge points. There is no physical meaning to the choice of hinge points. They are purely a method of describing a piecewise linear (in wavelength) curve in spectral space. To compute a surface emissivity at a particular frequency, the researcher should interpolate in frequency between the emissivities provided at adjacent hinge points. Nothing philosophical should be read into the choice of hinge points or why they vary among profiles.

References:

Wu and Smith (1997), Emissivity of rough sea surface for 8-13 μm: modeling and verification," Appl. Opt. 36, 2609-2619

New Products

See **V5_L2_Standard_Products_Quickstart.pdf** for a more detailed discussion of these new products.

Level 2 Standard Carbon Monoxide (CO) Product

Tropospheric CO abundances are retrieved from the 4.67 μm region of AIRS spectra as one of the last steps of the AIRS team algorithm. The AIRS 1600 km cross-track swath and cloud-clearing retrieval capabilities provide daily global CO maps over approximately 70% of the Earth. When day and night are combined for two days, full global coverage is achieved. This coverage is a major improvement over prior instruments and facilitates the study of global three-dimensional transport of CO in the atmosphere on near-daily time scales. Preliminary validation indicates AIRS CO retrievals are approaching the 15% accuracy target set by pre-launch simulations. AIRS CO product provides both total column burden and a volume mixing ratio profile.

Averaging kernels defining the vertical sensitivity of the AIRS CO product in 9 layers are provided. The layers have been chosen to match those of MOPITT to facilitate cross-comparison. The number of degrees of freedom, a measure of the amount of information in the CO retrieval, is also provided.

Level 2 Standard Methane (CH_4) Product

Tropospheric CH_4 abundances are also retrieved as one of the last steps of the AIRS team algorithm to provide daily global CH_4 maps over approximately 70% of the Earth. Preliminary comparison with airborne observations indicates AIRS CH_4 retrievals over the pressure range 200-650 mb are accurate to 1.5%. AIRS CH_4 product provides both total column burden and a volume mixing ratio profile.

Averaging kernels defining the vertical sensitivity of the AIRS CH_4 product in 7 layers are provided. The number of degrees of freedom, a measure of the amount of information in the CH_4 retrieval, is also provided.